REPELLENCY OF DEER AWAY BIG GAME REPELLENT® TO EASTERN COTTONTAIL RABBITS

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Abstract: Deer Away Big Game Repellent® (BGR) effectively deters browsing deer, most likely by the release of sulfur odors and volatile fatty acids. Because many herbivores avoid these odors, a logical inference is that BGR may repel herbivores other than deer. To address this possibility, we tested whether BGR was repellent to eastern cottontail rabbits (*Sylvilagus floridanus*). During fall–winter of 1994–95, we located 4 test sites (0.4–2.0 ha) in commercial nurseries in southern New Jersey. Different sites were planted to flowering pear (*Pyrus calleryana*), dogwood (*Cornus florida*), firebush (*Pyracantha coccinea*), and crab apple (*Malus* spp.). We split each site into 2 plots (0.2–1.0 ha), and plots then were randomly assigned to the treatment or control condition. After recording the number of damaged plants in each plot, we applied a 32.4% (mass/volume) solution of BGR to treated plots at the labeled rate of 3.8 L/400 plants. We applied water alone to plants in control plots. During a 21-day posttreatment period, we reassessed damage at 7-day intervals. During fall–winter of 1995–96, we repeated treatment and control applications, except that conditions were reversed (i.e., former control plots were treated with BGR and vice versa). We estimated rabbit numbers at each site during both years of the study and chemically evaluated the environmental persistence of BGR during the first year. Big Game Repellent was an effective repellent at all sites during both years of the study. These findings are consistent with the possibility that BGR represents an omnibus repellent for problem herbivores.

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Deer Away Big Game Repellent® (IntAgra, Minneapolis, Minnesota, USA) effectively deters browsing deer (Harris et al. 1983, Conover 1984, Scott and Townsend 1985, Conover and Kania 1987, Conover and Swihart 1990). Although putrescent whole-egg solids are the labeled active ingredient in this product, sulfur odors and volatile fatty acids most likely mediate repellency (Bullard et al. 1978). Herbivores avoid these odors (Mason et al. 1994).

Although the ecological basis of avoidance remains obscure, 2 testable explanations have been proposed. One stems from the observation that sulfur-containing chemicals and volatile fatty acids are common by-products of meat digestion. These degradation products are present in carnivore urine and feces, and they account for the repellency of these substances to herbivores and other potential prey (Epple et al. 1993, Nolte et al. 1994*a*, Lewison et al. 1995). The second explanation is that sulfurous odors are aversive because they are bioaccumulated by toxic plants, particularly those containing high levels of selenium (Morris 1970); thus, they act as reliable biological indicators of poisonous foods.

Irrespective of any underlying explanation(s), an obvious and testable hypothesis is that BGR could represent an omnibus repellent for herbivores. The development of such repellents is important for 2 reasons. First, while there is overwhelming public support for nonlethal methods of wildlife damage management, few chemical repellents are available (Mason 1997). Second, the cost of commercializing new repellents is often prohibitively high (Mason and Clark 1992); hence, broadening the utility of existing tools is attractive.

In the present experiment, we applied BGR to shrubs and trees in commercial nurseries as a candidate repellent for eastern cottontail rabbits (hereafter, rabbits). Various species of rabbits damage nursery stock and commercially planted timber throughout the United States (Burt and Grossenheider 1964, Chapman et al. 1980, Craven 1994, Conover et al. 1995). In the

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mid-Atlantic region, rabbit damage in nurseries can be severe and sometimes is of greater concern than damage caused by deer (M. R. Conover, Utah State University, personal communication). The New Jersey Department of Fish and Game routinely issues depredation permits as a means of handling growers' concerns (L. E. Widjeskog, personal communication). Some plants are girdled and killed, while others that survive damage have suppressed growth rates (Sullivan et al. 1993), reduced market value, or both. Sublethal injuries also increase susceptibility of trees to diseases by providing opportunities for infection by fungi and other pathogens (Sullivan et al. 1993). Use of BGR does not imply endorsement by the U.S. Department of Agriculture.

METHODS

The product label for BGR liquid spray (U.S. Environmental Protection Agency Registration No. 4866-10) lists the ingredients as 37% putrescent whole-egg solids and 63% inert ingredients. For application, we dissolved 4.6 kg of the concentrated product in 14.2 L of warm water to produce a 32.4% (mass/volume) solution.

We selected 4 nurseries in Cumberland County, New Jersey. At each site, we identified test sites that ranged in size from 0.4 to 2.0 ha. All sites at the first nursery were planted to 5-year-old flowering pear (684 trees), all sites at the second to 5-year-old dogwood (352 trees), all at the third to 3-year-old firebush (400 bushes), and all at the fourth to 4-year-old crab apple (200 trees). Plant densities ranged from 342 to 1,000 plants/ha. We chose these test species because growers claim that all 4 regularly sustain rabbit damage. All sites were tilled so there was no other vegetation in the vicinity of experimental shrubs and trees. However, windbreak vegetation (honeysuckle [*Diervilla lonicera*], multiflora rose [*Rosa multiflora*]) and brush piles within 10–20 m of each test site provided cover for rabbits and other wildlife. We estimated rabbit densities by walking 4 transects across each nursery on 4 consecutive nights between 1900 and 2200. The mean number of rabbits was higher in dogwood (0.6 ± 0.1 rabbits/transect meter; $\bar{x}$ ± SE) and firebush (0.7 ± 0.1) than in flowering pear (0.2 ± 0.1) or crab apple (0.3 ± 0.1).

Within nurseries, sites were separated from each other by at least 0.4 km to assure independence. During spring, rabbit home ranges in old-growth fields reportedly vary from 1.7 to 2.8 ha (Jones 1959, Trent and Rongstad 1974); hence, rabbits in nurseries that generally lack ground cover unlikely would visit >1 site. We split each site into 2 plots, each with approximately the same number of plants. Plots ranged in size from 0.2 to 1.0 ha. We randomly assigned 1 plot to the treatment condition and the other to the control condition. We separated plots with a 10-m buffer (to assure there would be no chemical contamination of control sites and so that rabbits could discriminate treated from control plants), and we marked plot boundaries with forestry flagging tape.

Application Procedures and Damage Evaluation

Testing occurred between November and March 1994–95 and 1995–96. We selected this time period because rabbit damage is most severe in winter. On the day of treatment (13 Nov 1994, 20 Nov 1995), we recorded the total number of damaged plants within each plot. We divided this number by the total number of plants in each plot to calculate percent damage. We defined rabbit damage as recent gnawing on the trunks (or branches) of plants within 40 cm of the ground. Gnawing close to the ground is typical of foraging by rabbits. We operationally defined recent damage as that in which plant tissues were still wet with sap. Next, we used Solo hand-sprayers (Model 422; Solo, Solingen, Germany) to apply water to control plots and BGR to treatment plots. To avoid any possibility of contamination, all control plots were sprayed first. The application rate was approximately 3.8 L of liquid/400 trees. This application is the rate specified on the product label for formulated liquid BGR. Spraying was limited to vegetation (trunks, branches) within 0.5 m of the ground.

During a 21-day posttreatment period, we visited each site at 7-day intervals. During each visit, we recorded the number of damaged plants as well as the total number of plants within each plot. We assumed that no increase in the number of damaged plants in treated plots (versus increasing numbers in control plots) was an indication that BGR effectively deterred rabbits.

We repeated treatment and control applications during the fall–winter of 1995–96, with the exception that application conditions were reversed (i.e., former control plots were treated with BGR, and vice versa). Chemical analyses

conducted during 1994–95 indicated treatment had dissipated completely within approximately 45 days posttreatment. After 3 weeks, we discontinued measurements during both years because of the onset of harvest. No plants were harvested during the 3-week posttreatment period in either year.

We estimated the environmental persistence of BGR residues during the first year of the study by measuring the concentrations of heptadecane and nonadecane on glass slides dipped in BGR mixture just prior to application and then exposed at 1 of the nursery sites. Heptadecane and nonadecane are constituents of the binder in BGR and are far easier to quantify than any of the active ingredients (i.e., volatile sulfur compounds, fatty acids). Concentrations of the latter are vanishingly small (Bullard et al. 1978) and would have been nearly impossible to detect. Because heptadecane and nonadecane are more volatile than the active ingredients (Budavari et al. 1989), detection of these substances indicated active ingredients also were present.

Beginning on the day of treatment, 3 slides were collected at 5-day intervals for 25 days. Slides were rinsed with 3 mL of ethyl acetate to transfer formulation residues to 25-mL screw-cap culture tubes. The tubes were shipped overnight to the National Wildlife Research Center (Fort Collins, Colorado, USA) for analysis. Residue masses were determined by measuring slide masses before and after removing the formulation residue; residues were typically <50 mg.

We mechanically agitated sample tubes containing BGR residue and ethyl acetate for 10 min on a horizontal shaker and then centrifuged them for 10 min at approximately 2,500 revolutions/min. We injected 1 μL of the extract from each tube into a gas chromatograph (Hewlett-Packard Model 5890; Hewlett-Packard, Avondale, Pennsylvania, USA) equipped with a 30- × 0.25-mm internal diameter poly(dimethylsiloxane) fused silica capillary column (DB-5; J & W Scientific, Folsom, California, USA) and a Hewlett Packard Model 5972 mass selective detector (MSD). We used electronic pressure control to maintain the helium carrier at 1.1 mL/min. The injection port temperature was 250°C, and the transfer line to the MSD was maintained at 280°C. The initial oven temperature was 40°C (0.5 min), followed by a temperature program of 15°C/min to a final temperature of 340°C (0.5 min). We operated the MSD in the scan mode, monitoring electron masses (m/e) from 45 to 300. The solvent delay was 4 min.

We evaluated the repeatability of our method for heptadecane assay by fortifying 45-day-old BGR residues (these residues no longer contained heptadecane) with known quantities of the analyte. Mean recovery of heptadecane from the fortified samples was 100% (SE = 0.57%). No heptadecane was observed in the 45-day-old controls.

We quantified samples versus external standards of heptadecane and nonadecane by determining the concentration (μg/g) of each analyte. Because the quantitative analysis was complicated by the varying contribution of water to the slides exposed to field conditions, we determined the ratio of heptadecane to nonadecane and then related these ratios to sampling date (time).

We calculated mean numbers of rabbits observed per transect meter, and we then evaluated these means in a 2-factor analysis of variance (ANOVA; nurseries, years). We used Tukey's tests to isolate significant differences among means ($P < 0.05$).

To evaluate treatment effects, we created difference scores by subtracting percent gnawing damage on the day of treatment from damage at 21 days posttreatment. These scores were then evaluated in a 3-factor ANOVA to test the null hypothesis that average difference scores were equal in treated and control plots. The factors were nurseries (4 levels), treatment conditions (2 levels), and years (2 levels). We do not report damage evaluation after 7 and 14 days posttreatment as levels of the time factor, because the pattern of results was identical to that after 21 days. We used Tukey's tests (Winer 1962:198) to isolate significant differences among means ($P < 0.05$).

RESULTS

Rabbit Numbers

We found a slight but significant difference among nurseries ($F_{1,9} = 9.0$, $P < 0.01$). More rabbits were detected in the nurseries planted to dogwood and firebush than in the nurseries planted to flowering pear or crab apple. There was no difference in rabbit numbers between years.

Table 1. Three-factor analysis of variance summary table for percent gnawing damage. Nurseries were nested within year and within block.

Source	SS	df	MS	*F*	*P*
Nursery	392.37	3	130.80	7.89	0.001
Block (nursery)	279.39	12	23.28	1.40	0.23
Treatment	1660.56	1	1660.56	100.15	0.001
Treatment × nursery	156.45	3	52.15	3.15	0.04
Year	0.81	1	0.81	0.05	0.83
Nursery × year	59.05	3	19.68	1.19	0.33
Block × year (nursery)	188.10	12	15.67	0.95	0.52
Treatment × year	2.40	1	2.40	0.14	0.71
Treatment × nursery × year	36.98	3	12.33	0.74	0.54

Damage

There were differences between treatments ($P < 0.001$), among nurseries ($P < 0.001$), and an interaction between these terms ($P < 0.04$; Table 1). Examination of the treatment effect showed that while damage continued in control plots ($\bar{x}$ difference score = 12.2 ± 1.3; $\bar{x}$ ± SE), it slowed considerably in treated plots (2.4 ± 0.4). Examination of the nurseries effect showed that gnawing damage was least in the nursery planted to crab apple and greatest in the nursery planted to dogwood. Post hoc examination of the interaction showed that treatment had the greatest effect in the nursery planted to firebush, the least effect in the nursery planted to crab apple, and intermediate effects in the nurseries planted to flowering pear and dogwood (Fig. 1).

Chemical Analysis

Our evaluation of the relation between the heptadecane:nonadecane ratio and time produced a coefficient of determination of 0.772, with a slope of −0.00736 and a *y*-intercept of 0.57. Although the ratio diminshed over time (suggesting evaporation), heptadecane and nonadecane were present throughout the treatment period (Fig. 2). The presence of these substances suggests the active ingredients (i.e., volatile sulfur compounds and fatty acids) also were present throughout the experimental period (3 weeks posttreatment).

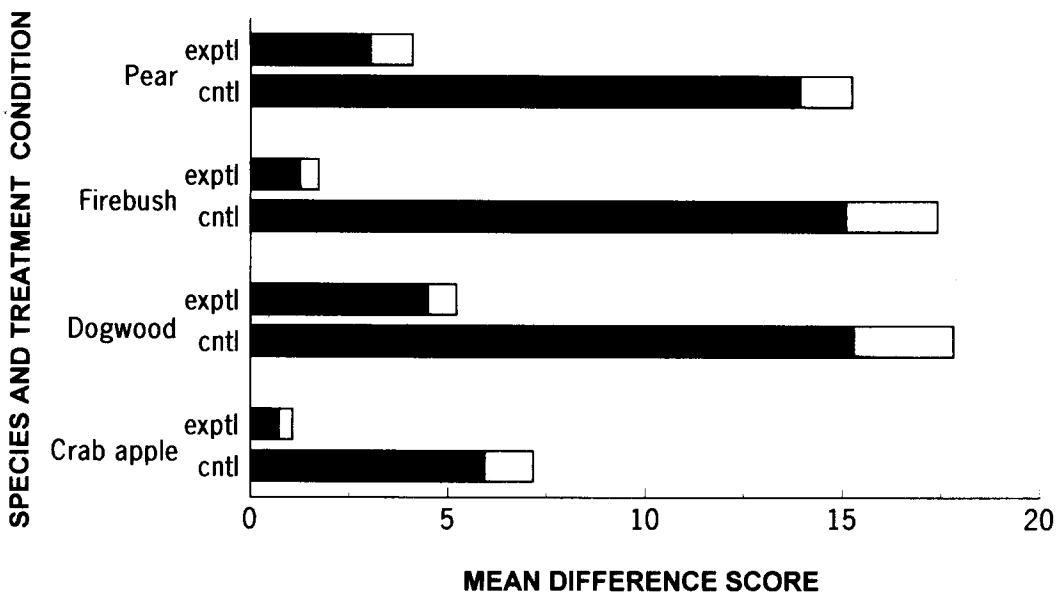

Fig. 1. Mean difference scores calculated by subtracting percent damage on the day of treatment from damage on posttreatment day 21. Plantings were sprayed with Deer Away Big Game Repellent® (exptl) or water (cntl) at the rate of 32.4% (mass/volume) of formulated product. Open caps on bars represent standard errors of the means.

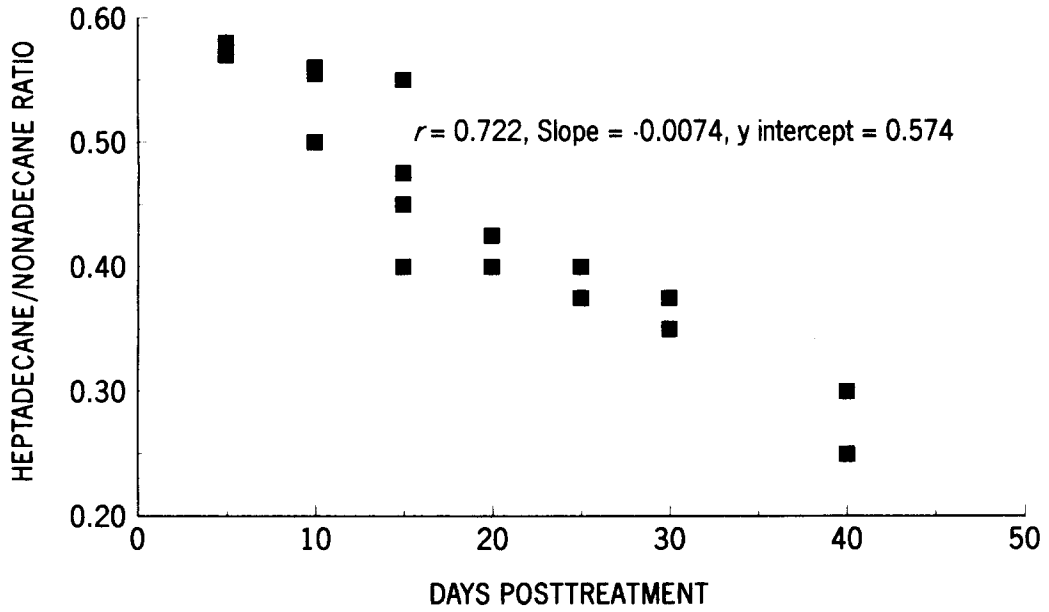

Fig. 2. Heptadecane:nonadecane ratios computed from the chemical evaluation of Big Game Repellent samples on glass slides collected in the field over a 40-day posttreatment period.

DISCUSSION

We found that treated plots received less damage than control plots for 3 weeks posttreatment. This result is roughly consistent with the avoidance that others have reported in studies of BGR repellency to deer (Harris et al. 1983, Conover 1984, Scott and Townsend 1985, Conover and Kania 1987, Conover and Swihart 1990, Milunas et al. 1994). Interestingly, there was an interaction between the effectiveness of BGR and plant species to which it was applied. The repellent appeared to have the greatest beneficial effect with firebush, and the least with crab apple. Several factors may have contributed to this differential effect. One factor might be differences in rabbit numbers among sites; another is that there may have been an interaction between the aversiveness of BGR and the inherent palatability of the plants. Additional investigations are warranted to explore these possibilities.

MANAGEMENT IMPLICATIONS

Our experiments involved only 4 nurseries over a 2-year period. Nonetheless, our results have clear practical implications. All rabbit repellents currently registered for use contain relatively dangerous chemicals such as disulfiram (thiram®), which is a potent emetic that can be absorbed transdermally (Stecher et al. 1968); human irritants like capsaicin; or bitter tastes like denatonium benzoate, which do not repel herbivores (Andelt et al. 1994, Nolte et al. 1994*b*). Hence, BGR may represent a safe and effective alternative to these other materials.

From a theoretical viewpoint, our findings are consistent with evidence that sulfurous odors and volatile fatty acids are generally repellent to herbivores, regardless of species, genus, or taxa (Mason et al. 1994, Mason and Clark 1995). We speculate that BGR may be useful as a repellent for a spectrum of problem herbivores, including muskrat (*Ondatra zibethica*), nutria (*Myocastor coypus*), marmots (*Marmota* spp.), and beaver (*Castor canadensis*). Studies that evaluate this proposition appear warranted, given the absence of effective, registered repellents for these species.

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